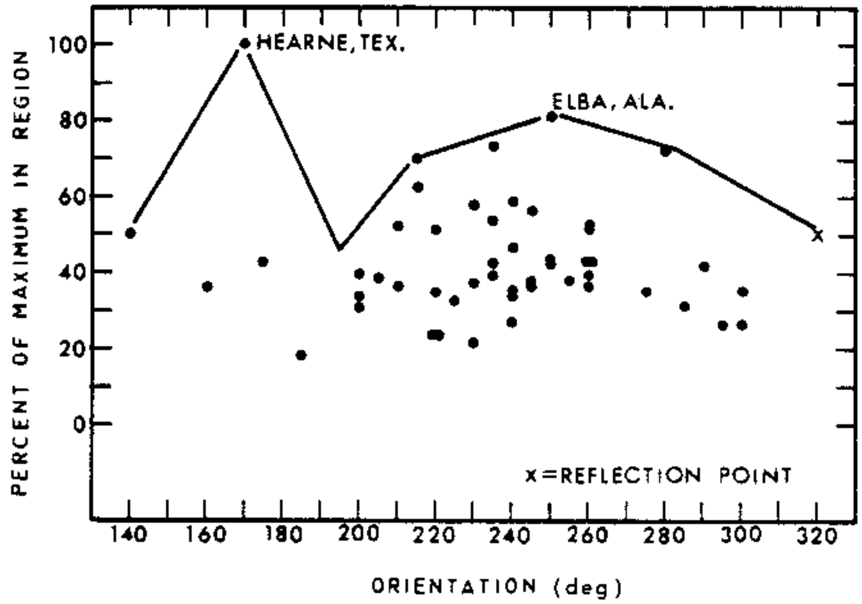

Figure 9.—Distribution of isohyetal orientations for 50 major storms (from sample listed in the appendix) that occurred in the gulf coast subregion.

possibly a complex cell). Such a system is expected to have equal intensity at any orientation. An area size of 300 mi^2 was chosen as the smallest storm area for which a reduction should be applied. A rational argument can also be developed to say that if we limit reduction of PMP for orientation to storm area sizes of 300 mi^2 and larger, it is unreasonable to expect that a discontinuity occurs at 300 mi^2. On this basis, there should also be some limit at which the maximum reduction of 15% applies. Between these limits, a reduction between 0 and 15% applies. Although we have no data to support our decision, we chose to set a limit of 3,000 mi^2 (ten times the lower limit of 300 mi^2) as the area above which 15% reduction is possible.

To use figure 10 for pattern areas greater than 300 mi^2 consider the diagonal lines provided for guidance. These lines have been drawn for every 500 mi^2 up to 3,000 mi^2, and intermediate 100-mi^2 areas are indicated by the dots along the right margin. By connecting the vertex in the upper left with the appropriate dot on the right, the user can determine the adjustment factor corresponding to the orientation difference noted along the abscissa. As an example, for a 1,000-mi^2 isohyetal pattern whose orientation differs by 57° from that determined from figure 8, the adjustment factor read from figure 10 is 97.3%. Note for orientation differences of 65° or larger, the adjustment factor is that given by the scale along the right margin for the respective areas.

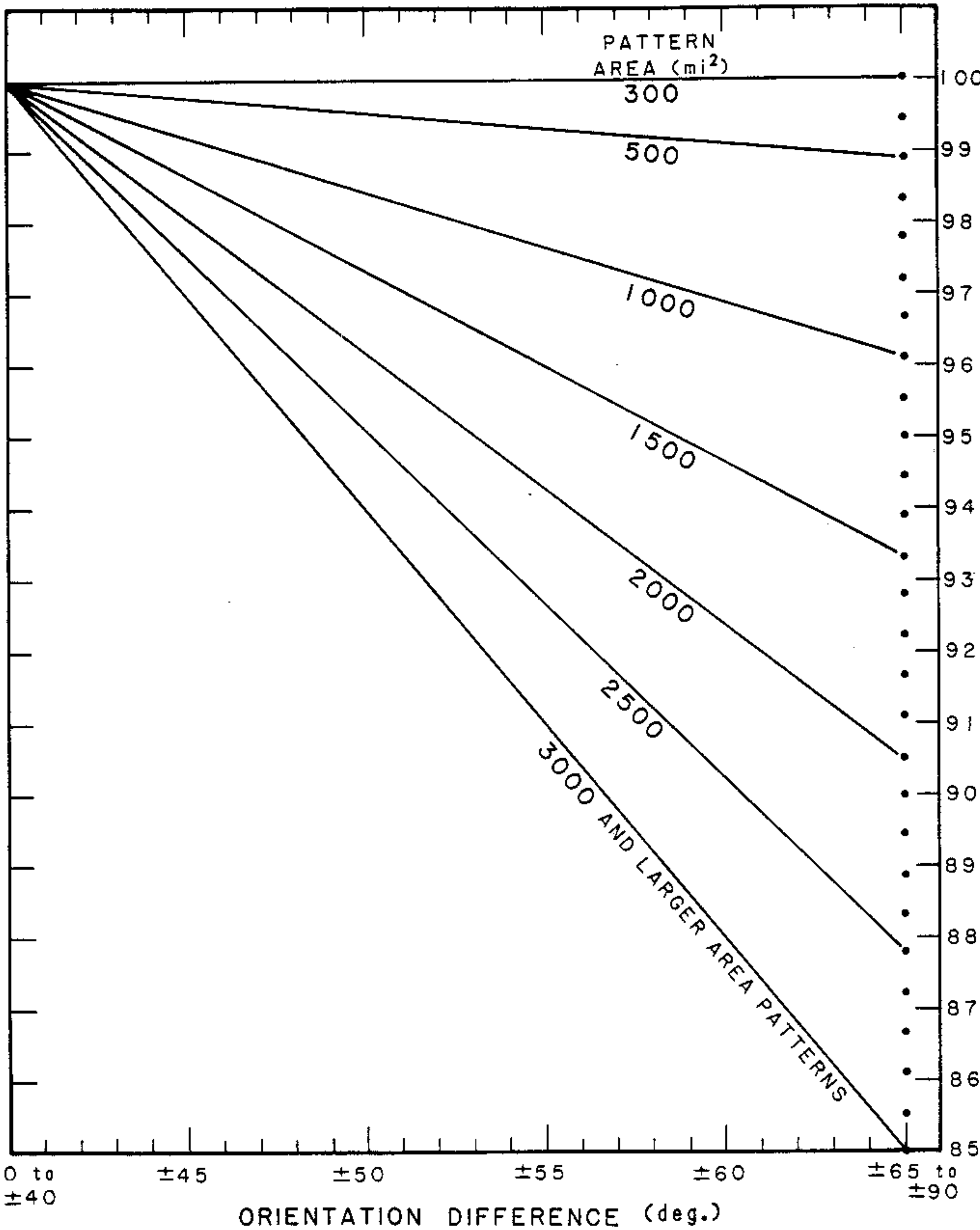

Figure 10.—Model for determining the adjustment factor to apply to isohyet values as a result of placing the pattern in figure 5 at an orientation differing from that given in figure 8 by more than 40°, for a specific location.

4.4.4 Noncoincidental rainfall pattern

One may find through a trial and error approach that, in some hydrologic situations, an isohyetal pattern orientation different from that of the drainage may give a more critical result than that obtained when the orientations coincide. This appears to be possible, for some drainages, because there is a tradeoff between the volume one gets from a rainfall pattern coincident with the drainage, but requiring maximum reduction for orientation relative to PMP, and that from a noncoincident placement of the isohyetal pattern with less or no orientation reduction.

To illustrate, assume a precipitation pattern placed on a hypothetical drainage has an orientation differing more than 65 degrees from that given in figure 8 for the location. The recommended procedure in this study is to apply the maximum reduction allowed in figure 10 to all the isohyet values, for orientation differences of this magnitude. However, it might be possible to obtain a more hydrologically critical result if the rainfall pattern placed over the drainage and the drainage orientations were kept dissimilar and the isohyet values were not reduced at all. Because it appears it may be necessary to check a wide range of possible orientation arrangements to determine the hydrologically most critical relationship between PMP and rainfall pattern on drainage orientations, we offer only limited guidance. The most likely situations where non-fit and no reduction would be important are those that involve maximum reductions to PMP for low drainage shape ratios (≤ 2), i.e., "fat" drainage shapes.

Another consideration that needs to be noted is that the discussion of pattern placement in this report is primarily directed at drainages that are not affected by orographic influences (the nonorographic region in HMR No. 51). Should it be of interest to estimate PMP from HMR No. 51/52 techniques applied to a drainage in the orographic region, it is necessary to judge whether placement of the pattern to center in the drainage or to align with the drainage is meteorologically possible. An example is the following: if a tropical storm is taken as the PMP storm type for a drainage on the western slopes of the southern Appalachian Mountains, it is unlikely that the isohyetal pattern can be realistically centered more than a few miles west of the ridgeline. Thus, in the orographic regions, one needs to recognize the storm type most likely to give PMP and then determine where and how the idealized pattern can be placed.

4.4.5 Comparison to other studies

There are only a few references to orientation of isohyetal patterns in the meteorological literature. HMR No. 47 (Schwarz 1973) discusses the subject of orientation preferences and reduction to PMP for pattern orientation in the Tennessee Valley. Schwarz concludes that 100% of PMP would apply to orientations between 195 and 205 degrees. Riedel (1973) suggests that 100% of PMP applies to orientations between 200 and 280 degrees for the Red River of the North and the Souris River in North Dakota. For these locations, figure 8 gives central orientations between 210 and 245 degrees, and between 240 and 255 degrees, respectively. Our ± 40° range for full PMP, when added to these central orientations, permits general agreement between these two studies and the present study, although in general we allow for more westerly components than were reported in the earlier studies.

Huff (1967) reported that in a detailed study of 10 large scale storms (Illinois) in the period 1951-1960 in which 12-hour rainfall exceeded 8 in. at the storm center, the median orientation was 270 degrees. This compares with a range of 245 to 255 degrees for central orientations across Illinois in figure 8. A later study (Huff and Vogel 1976) reported that for heavy rainstorms in northeastern Illinois, 84 percent had orientations between 236 and 315 degrees.

4.5 Meteorological Evaluation of Isohyetal Orientations

We believe the basis for the orientations in figure 8 is related to the occurrence of certain meteorological factors conducive to optimum rainfall production. We know that certain combinations of storm movement, frontal surfaces, and moisture inflow can influence the orientation of observed rainfall. We also know that the movements of storm systems are often guided by the mean tropospheric winds (generally represented by winds at the 700- to 500-mb level). An attempt is made in this section to understand some of these large-scale factors relative to the occurrence of the major rainfall events listed in table 11. These factors are listed in table 13. Note that the isohyetal orientations for the total storm given in column 6 of this table are those observed for these individual rainfall cases (from table 11) and are not to be confused with the orientations appearing in figure 8 for the generalized analysis.

The following comments explain the information given in table 13:

Col. 1 location of maximum rainfall

Col. 2 date within the period of extreme rainfall on which the greatest daily rainfall occurred, as derived from selected mass curves shown in "Storm Rainfall" (U. S. Army Corps of Engineers 1945-)

Col. 3 rainfall type categories: **tropical** (T) for all extreme rains that occur as the result of passage of a tropical cyclone within 200 miles of the site of heavy rain; **modified tropical** (MT) for those extreme rains that appear to be derived from moisture associated with a tropical cyclone at some distance, or whose moisture has fed into a frontal system that has moved to the vicinity of the rain site. The presence of tropical cyclones has been determined from Neumann et al. (1977). Tropical cyclone rains that become extratropical are also labeled MT; **general** (G) includes all rains for which no tropical storm was likely involved; **local** (L) for relatively short-duration small-area storms.

Col. 4 the orientation (direction storm is moving from) of the track of low-pressure center passing within 200 miles of the heavy rain, for the date of closest passage of the rain center. When no low-pressure center passes near the rain site, "none" is listed in table 13.

Table 13.—Meteorological factors pertinent to isohyetal orientation for major storms used to develop regional analysis (fig. 8)

Column 1	2	3	4	5	6
Storm center	Date of max. daily rain	Type of rain-storm	Orient. of storm track	Orient. of front. surface	Observed orient. of iso. pat.
1. Jefferson, OH	9/13/1878	MT	190	135	190
2. Eutaw, AL	4/16/00	G	none	210	230
3. Paterson, NJ	10/09/03	MT	100	180	170
14. Beaulieu, MN	7/19/09	G	none	none	285
17. Altapass, NC	7/16/16	MT*1	none	none	155
18. Meek, NM	9/16/19	MT*2	none	none	200
19. Springbrook, Mt.	6/19/21	G	260	200	240
20. Thrall, TX	9/09/21	MT*3	none	none	210
21. Savageton, WY	9/28/23	G	none	none	230
22. Boyden, IA	9/17/26	G	none	210	240
23. Kinsman Notch, NH	11/04/27	MT*4	none	180	220
24. Elba, AL	3/14/29	G	none	210	250
25. St. Fish Htchy.,TX	7/01/32	G	none	240	205
27. Ripogenus Dam, ME	9/17/32	MT	185	160	200
30. Hale, CO	5/31/35	L	none	090	225
37. Hayward, WI	8/30/41	G	none	250	270
38. Smethport, PA	7/18/42	L	none	190	145
39. Big Meadowns, VA	10/15/42	MT*5	none	none	200
42. Collinsville, IL	8/16/46	G	none	260	260
44. Yankeetown, FL	9/05/50	T	180*8	none	205
45. Council Grove, KS	7/11/51	G	none	250	280
48. Bolton, Ont. Can.	10/16/54	MT	200	200	190
49. Westfield, MA	8/18/55	MT	175	none	230
51. Sombreretillo, Mex.	9/21/67	T	020	none	220
53. Zerbe, PA	6/22/72	MT	150	220	200
54. Broome, TX	9/17/36	MT*6	none	none	230
55. Logansport, LA	7/23/33	T	240	245	215
56. Golconda, IL	10/05/10	G	none	235	235
57. Glenville, GA	9/27/29	MT*7	230*7	none	180
58. Darlington, SC	9/18/28	T	230	220	205
59. Beaufort, NC	9/15/24	MT	240	210	235

LEGEND

T - Tropical MT - Modified Tropical

G - General L - Local

*1 - Trop. cycl. dissipated in central Georgia on 14th
2 - Hurricane dissipated in southwestern Texas on 15th
3 - Hurricane dissipated on Texas-Mexico border on 8th
4 - Tropical cyclone headed north @ 36°N, 80°W. mid-day 3rd
5 - Tropical cyclone dissipated in eastern North Carolina on 12th
6 - Tropical cyclone dissipated near Del Rio, TX on 14th
7 - Hurricane at Key West on 27th, track given for 30th
8 - Storm looping on 4-5th

Col. 5 the orientation (only one end of the 2-ended line given) of the frontal surface if the front is within 100 miles of the rain center (from United States Daily Weather Maps) for the date of greatest daily rainfall. When no frontal surface appears near rain site, "none" is listed in table 13.

Col. 6 the orientation of observed rainfall pattern for the total storm from table 11

Eighteen of the 31 rains in table 13 come from tropical or modified tropical storms. A logical question is whether the orientation of the rainfall pattern is the same as the orientation of the storm track. Eleven of the thirteen rainfalls that have storm track information show agreement within 50 degrees between the storm track and rainfall orientations.

Some of the modified tropical cyclone rains showed that maximum rainfall occurred where tropical moisture interacted with a frontal surface generally approaching from the west or northwest. This kind of interaction and the complexity involved in ascertaining the cause for the particular isohyetal orientation is illustrated in the case of the Zerbe, Pa. storm (6/19-23/72). Figure 11 shows a cold front through the Great Lakes at 1200 GMT on the 21st that moved eastward and became stationary through western New England by 1200 GMT on the 22nd. The track of the tropical cyclone center is shown by 6-hr positions. After 1200 GMT on the 22nd, the storm center appears to be attracted toward the approaching frontal trough position and recurves inland through Pennsylvania. The orientation (approx. 200°) of the total-storm isohyetal pattern is plotted in figure 11 for comparison. Although the front appears to be dissipating with the approach of the tropical cyclone, the orientation of the total-storm rainfall would suggest that the effect of the frontal surface as a mechanism for heavy rainfall release was important. Thunderstorms along the frontal surface may have moved in a northeasterly direction (200°), steered by the upper-level winds. Since all of these features are in motion, it is likely that the orientation of the isohyetal pattern is the composite result of several interactions. One additional factor that has not been discussed is the effect of the Appalachian Mountains. The ridges comprising these mountains also have a northeast-southwest orientation. We are unable to say at this time how the interaction between moisture flows and these terrain features contribute to the overall orientation of the precipitation pattern.

The Springbrook (6/17-21/21) and Savageton (9/27-10/1/23) storms were associated with nontropical low-pressure centers to the south of the respective rainfall maxima, around which moist air drawn from gulf latitudes encountered strong convergence to release convective energy.

Reviewing the results given in table 13, one may ask, what meteorological feature provides the source of precipitation for those storms that show "none" in columns 4 and 5. To answer this question requires studies beyond the scope of this discussion, but in many instances we believe the precipitation was caused by horizontal convergence of very moist air. This convergence in most instances was due to meteorological conditions, while in others it may have been enhanced by terrain features.

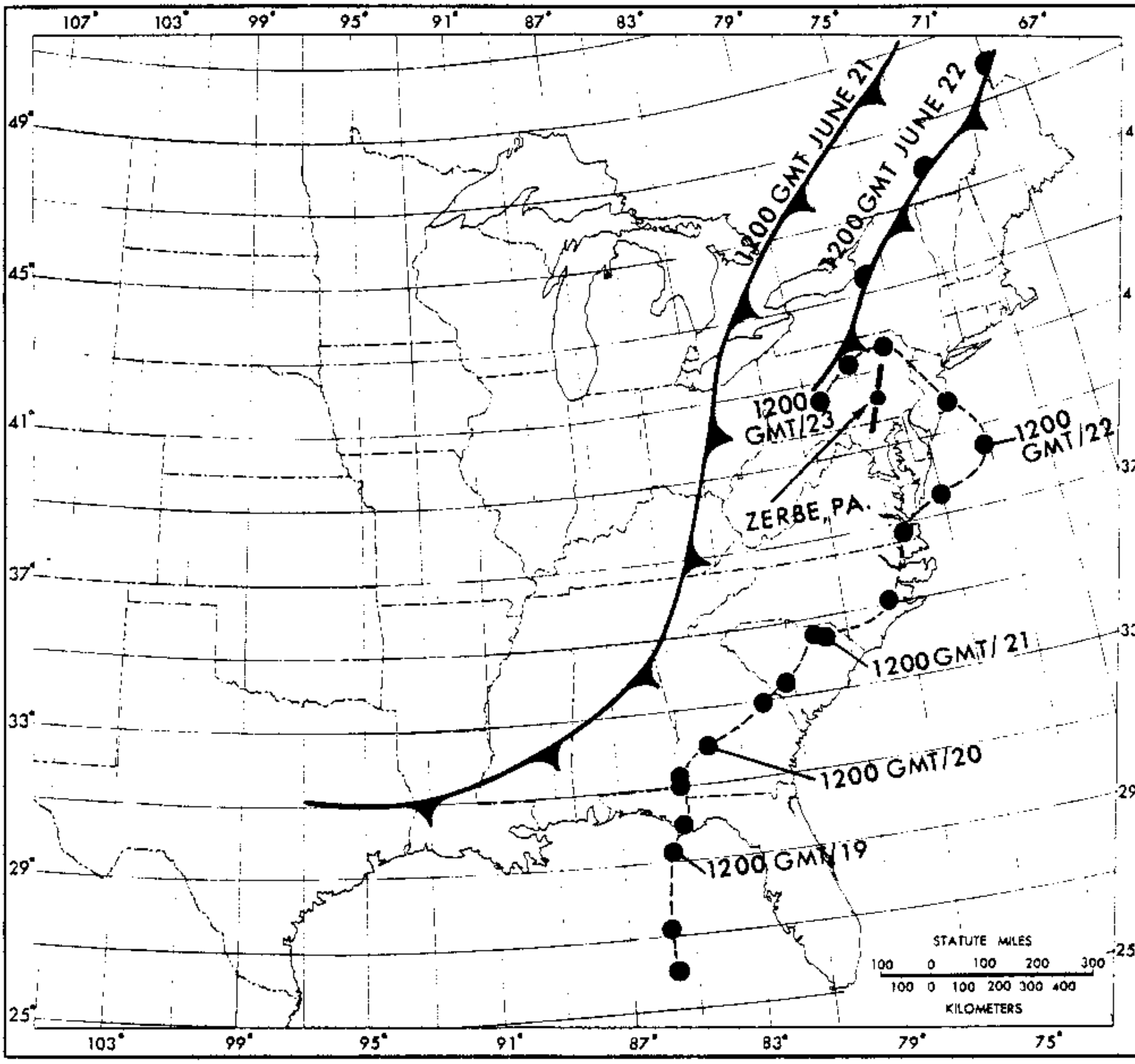

Figure 11.—Track of hurricane Agnes (6/19-22/72) showing frontal positions and orientation of the greatest 20,000-mi^2 precipitation area centered at Zerbe, PA.

The Golconda, Illinois, storm (10/3-6/10) is representative of most of the other major storms in table 13 in which the isohyetal orientation can be more closely related to the orientation of the frontal surface. For this storm figure 12 shows a weak and dissipating cold front (A) approaching Golconda from the west on the 3rd and 4th. Farther west on the 4th a second cold front (B) is passing through the Dakotas and moves rapidly eastward to a position southwest-northeast through the Great Lakes on the 5th. Twenty-four hours later this second front has passed eastward of Golconda. Prior to its passage, strong southerly surface winds bring moist tropical air northward through the Mississippi Valley. It is presumed that this moist air upon meeting the frontal surface, is lifted to a level at which convective lifting takes over. Thunderstorms, or local storms, triggered along the frontal surface produce the observed rainfall orientation.

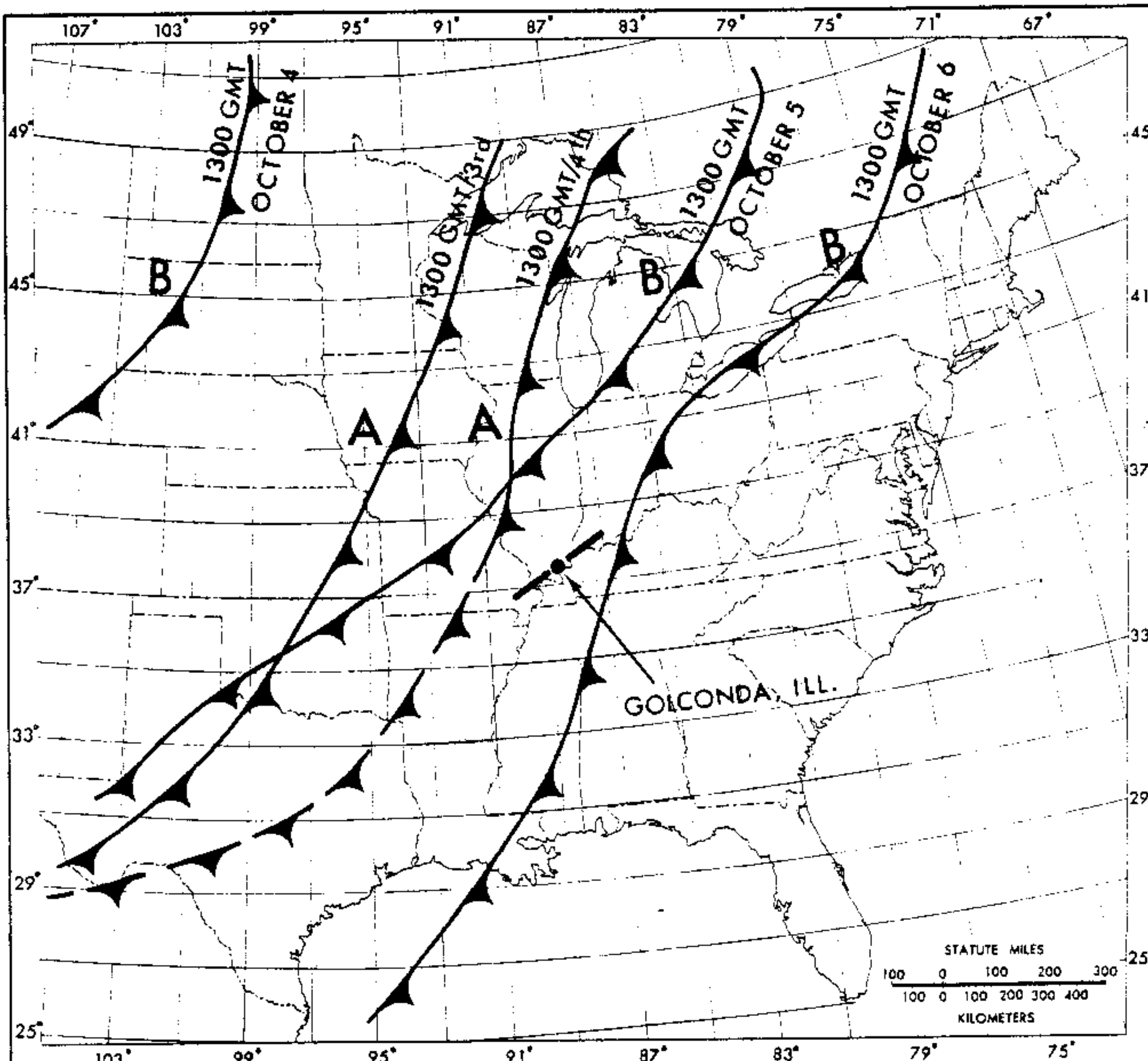

Figure 12.—Frontal positions and orientation of the greatest 20,000-mi^2 precipitation area centered at Golconda, IL (10/3-6/10).

Almost all of the 31 major storms listed in table 13 included thunderstorm-type bursts of heavy rain. Tendencies for these short-duration bursts are evident in major portions of the mass curves (not shown here) for each storm. Thunderstorms imbedded within widespread rain patterns are common to major rainfalls in the study region. Since thunderstorms are involved, we speculate that the isohyetal pattern orientations probably are controlled to some degree by the upper-level flows (see Newton and Katz 1958, for example).

Maddox et al. (1973) studied the synoptic scale aspects of 151 flash floods, 113 of which occurred east of the 105th meridian. (One-third of these had maximum precipitation amounts equal to or exeeding 10 in.) Their results showed that the winds aloft tend to parallel the frontal zone during these events. They also showed that 500-mb winds were representative of the winds aloft between 700 and 200 mb, and that mean 500-mb winds for these events varied between 220 and 250 degrees (standard deviation of about 30°). Although they do not discuss regional variation, this range of 500-mb winds agrees well with the orientations adopted for PMP-type rain patterns (fig. 8).

Upper-level winds are routinely available only after December 1944 (Northern Hemisphere Daily Maps). Seven storms in table 12 occurred after this date, for which the 500-mb winds were 280° at Collinsville, Illinois, 260° at Council Grove, Kansas, 210° at Bolton, Ontario, 215° at Westfield, Massachusetts, 020° at Sombreretillo, Mexico, and 220° at Zerbe, Pa., the 500-mb winds were indeterminate for the Yankeetown, Florida rain site because of the occurrence of a small closed low system aloft associated with the surface hurricane. There is agreement within ± 20° between 500-mb winds and the orientation of heaviest rainfall for these storms. Had 500-mb information been available for more of the storms, it is expected that this association would be further supported.

4.6 Application to HMR No. 51

This study of isohyetal orientation of major rainfalls has produced guidelines we recommend for use in adjusting the volume of rainfall obtained from the isohyetal patterns of the 6-hr PMP increments. Figures 8 and 10 are used to reduce the PMP for certain area sizes if the orientation of the pattern placed on the drainage does not fall within ± 40° of the prescribed PMP orientation for that site. To apply these results use the following steps:

1. For a specific drainage, locate its center on figure 8 and linearly interpolate the central orientation for PMP at that location.

2. Obtain the orientation of the isohyetal pattern that best fits the drainage. In the orographic region of HMR No. 51, the orientation of the pattern may not fit the drainage but will be controlled by terrain and meteorological factors.

3. If (1) differs from (2) by more than ± 40° the isohyet values for each of the 6-hr increments of PMP are to be reduced in accordance with figure 10. Differences in orientations of more than ± 65° require the maximum reduction. The reduction that is applicable, however, is a function of the storm pattern area size with no reduction if 300 mi^2 or less, and a maximum of 15% if 3,000 mi^2 or more.

5. ISOHYET VALUES

5.1 Introduction

When considering the spatial distribution of rainfall over a drainage, a question that needs to be answered is how concentrated the rain should be. Keep in mind that the concentration or distribution of the drainage-average PMP does not change the total rain volume for idealized elliptically shaped drainages. For this report, the spatial distribution is set by the values of isohyets in the isohyetal pattern. Part of this question has been answered in chapter 3, where we developed an idealized pattern shown in figure 5. This chapter, therefore, deals with determination of the values to assign the isohyets in that figure for each 6-hr increment. Chapter 6 treats isohyet values for shorter durations.

One manner of distributing the drainage-average PMP is to apply the depth-area relation of PMP itself, that is, giving PMP for all area sizes within any particular drainage. Studies made for HMR No. 51, however, showed that the storms, controlling or setting PMP for small area sizes, often did not control for large areas and vice versa. Therefore, we assume that rainfall for areas less than the area of the PMP pattern will be less than the corresponding PMP, and that the depth-area relation of PMP should not be used to determine the isohyet values. The term adopted for the depth-area relations in a storm is thus a "within-storm" relation, since it serves to represent a relation for which one storm controls over all area sizes less than PMP. We have made a similar assumption, in this study, that such a curve also applies to areas larger than the area for which average PMP is being distributed (referred to as without-storm curves, see fig. 1).

If one applies the pattern in figure 5 to a drainage in the orographic region in HMR No. 51 there will be an additional modification to the distribution of PMP brought about by terrain effects. It is not the intent of this report to discuss how these local modifications are derived, but their effect will be to modify or warp the pattern in the direction of major storm patterns that have been observed on the drainage. Because these modifications are a function of the specific drainage, it is recommended that each application of HMR No. 51/52 in the orographic region be the subject of an individual study.

5.2 Within/Without-Storm D.A.D Relations

From consideration of the possible depth-area-duration (D.A.D) relations, we recommend a within/without-storm distribution of PMP for a drainage that falls somewhere between a flat average value (uniform distribution) and the depth-area relation of PMP. Such a relation can be patterned after depth-area relations of major storms. The within-storm technique has been used in several HMR reports (Riedel 1973, Goodyear and Riedel 1965). In this chapter, we use the generalization of such within-storm depth-area relations combined with without-storm relations to set the values of isohyets for the adopted pattern.

The following sections describe the method used to obtain isohyet values at one location and explain how we generalized the procedure throughout the region. Since the method is somewhat complex, it is necessary to present a more detailed description of its development.

To begin this discussion several questions are posed: a.) For which 6-hr PMP increments do we need isohyetal values?, b.) How are within/without-storm depth-area relations for 6-hr PMP increments in (a) determined?, c.) How are isohyetal profiles for a 6-hr incremental PMP used to obtain isohyet values?, and d.) How can we generalize (c) to provide isohyet values for areas between 10 and 20,000 mi^2 anywhere within the study region?

5.2.1 PMP increments for which isohyet values are required

Record storm rainfalls show a wide variation in D.A.D relations. They all indicate a sharp decrease with area size for the maximum 6-hr rainfall. The remaining 6 hr rainfall increments may vary from showing a decrease, an increase, or no change with increasing area size. This mixture may be due in part to a storm with a complex combination of both high and low rainfall centers with maximum depths controlled by several centers. However, for internal consistency no increase in incremental PMP values with increasing area size was allowed in HMR No. 51. If it were, it would designate a low rather than a high rainfall center, or a doughnut type configuration.

We have let the D.A.D relations of PMP in HMR No. 51 set the number of increments for which areal variation is required. These show that most spatial variation occurs in the largest 6-hr increment, and practically none, if any, occurs after the third greatest 6-hr increment. This is to say, as an example, that the fourth greatest 6-hr incremental PMP determined by subtracting 18-hr PMP from 24-hr PMP varies only slightly, if at all, with area size. Therefore, we recommend distributing incremental PMP for only the three greatest 6-hr PMP increments. The remaining nine 6-hr PMP increments are used as storm pattern averages, that is, as uniform depths over the pattern area used for distributing PMP.

5.2.2 Isohyet values for the greatest 6-hr PMP increment

Since we need to obtain all isohyet values for only the three greatest 6-hr PMP increments, we have chosen to discuss each increment separately. The procedure we followed began with consideration of the depth-area-duration relations taken from major storms in table 1; we used these data to develop within/without-storm curves which we then converted to isohyetal profiles. Finally, we generalized these profiles in developing a set of nomograms that give isohyet values for any area size.

5.2.2.1 Depth-area relations. We chose to consider depth-area data only for those storms in table 1 that provided moisture maximized transposed depths within 10 percent of PMP for 6 hr. This condition reduced our sample to the 29 storms in table 14. Next, depth-area data for these storms, taken from the appendix of HMR No. 51, were used to form all available ratios of depths. For example, for 10 mi^2, divide the 10-, 200-, 1,000-, 5,000-, 10,000-, and 20,000-mi^2 depths by the 10-mi^2 depth. Then form all the ratios for 200 mi^2 and so on to the 20,000-mi^2 ratios. Those within/without-storm average ratios, since they are individually done for each storm, are thus given as a percent of the respective standard area size value.

Table 14.--Major storms from table 1 used in depth-area study (index numbers refer to listing in table 1)

1. Jefferson, OH	15. Merryville, LA	36. Hallett, OK
2. Wellsboro, PA	16. Boyden, IA	38. Smethport, PA
3. Greeley, NE	23. Kinsman Notch, NH	40. Warner, OK
6. Hearne. TX	24. Elba, AL	44. Yankeetown, FL
7. Eutaw, AL	27. Ripogenus Dam, ME	45. Council Grove, KS
8. Paterson, NJ	28. Cheyenne, OK	46. Ritter, IA
10. Bonaparte, IA	29. Simmesport, LA	47. Vic Pierce, TX
12. Knickerbocker, TX	30. Hale, CO	51. Sombreretillo, Mex.
13. Meeker, OK	34. Grant Township, NE	53. Zerbe, PA
14. Beaulieu, MN	35. Ewan, NJ	

Because of the relatively small sample of storms, we chose not to consider any regional variation that may exist in these storm ratios. This conclusion is believed justified at this time, however, future study should investigate regional variation in depth-area relations.

The ratios obtained for the 29 storms were then averaged and the average was plotted against area size. Since some storms are relatively small in area size while others are much larger than 20,000 mi^2, not all 29 storms have all the depth data needed to complete all ratios, and the larger area averages are made from fewer and fewer storms. The plotted data are smoothed into a consistent set of curves as shown in figure 13. The solid lines represent within-storm averages for areas less than that of the PMP, and the dashed lines represent without-storm averages for areas greater than the area for PMP, the residual precipitation. Because of our assumption of no regional variation, figure 13 applies to the entire region.

Now, by applying the curves in figure 13 to the storm area averaged PMP in HMR No. 51 at a specific location, we obtain a set of curves of the form shown in figure 14. The solid curve connects the 6-hr PMP for various area sizes (in parentheses). The short-dashed lines are the within-storm curves for areas less than the PMP area, and the long-dashed lines are the without-storm curves for areas larger than the PMP area. It is the long-dashed curves covering the residual or without-storm precipitation that are unique to this study. To use figure 14, if one considers PMP for a particular area size, say 1,000 mi^2, enter the figure on the ordinate at 1,000 mi^2, and move horizontally to the solid line to obtain the value of PMP at this location, 15.5 in. To determine the corresponding precipitation during this PMP storm for any smaller (larger) area size in that 1,000-mi^2 PMP pattern, follow the short-dashed (long-dashed) curves from the point of PMP. In this figure, we have treated the juncture of within- and without-storm curves as a discontinuity, although a tangential approach to the point of PMP may be more realistic. We assume that this decision has little affect on our procedure and on the results obtained. If the PMP is for some area size other than the standard areas shown, then interpolation is necessary, using the indicated curves as guidance.

5.2.2.2 Isohyetal profile. Figure 14 gives a plot of the within/without-storm precipitation relative to area size. In the application of our idealized elliptical pattern, we need to know the value of the isohyet that encloses the specified areas. That is, if we drew a radial from the center of the pattern to the outermost isohyet, it would intersect all the intermediate enclosed isohyets. If we then plotted the value of the isohyet against the enclosed area of that isohyet, we could draw a curve through all the points of intersection and obtain a profile of isohyet values for a particular pattern area of PMP. A different distribution pattern of PMP would give a different isohyetal profile.

For 37°N, 89°W, we have converted the within/without-storm curves in figure 14 to the corresponding isohyetal profiles shown in figure 15. The curves in figure 15 were computed by reversing the process generally followed for deriving D.A.D curves from an isohyetal profile. This process has been briefly outlined in the "Manual for Estimation of Probable Maximum Precipitation" (World Meteorological Organization 1973). A necessary assumption for this conversion procedure is that of equivalent radius. That is, since the radius of an ellipse varies with the angle between a particular radius and the axis, different profiles would be obtained, depending upon which radial is chosen. To avoid this problem, we approximate the elliptical pattern by a circular pattern of equivalent areas and

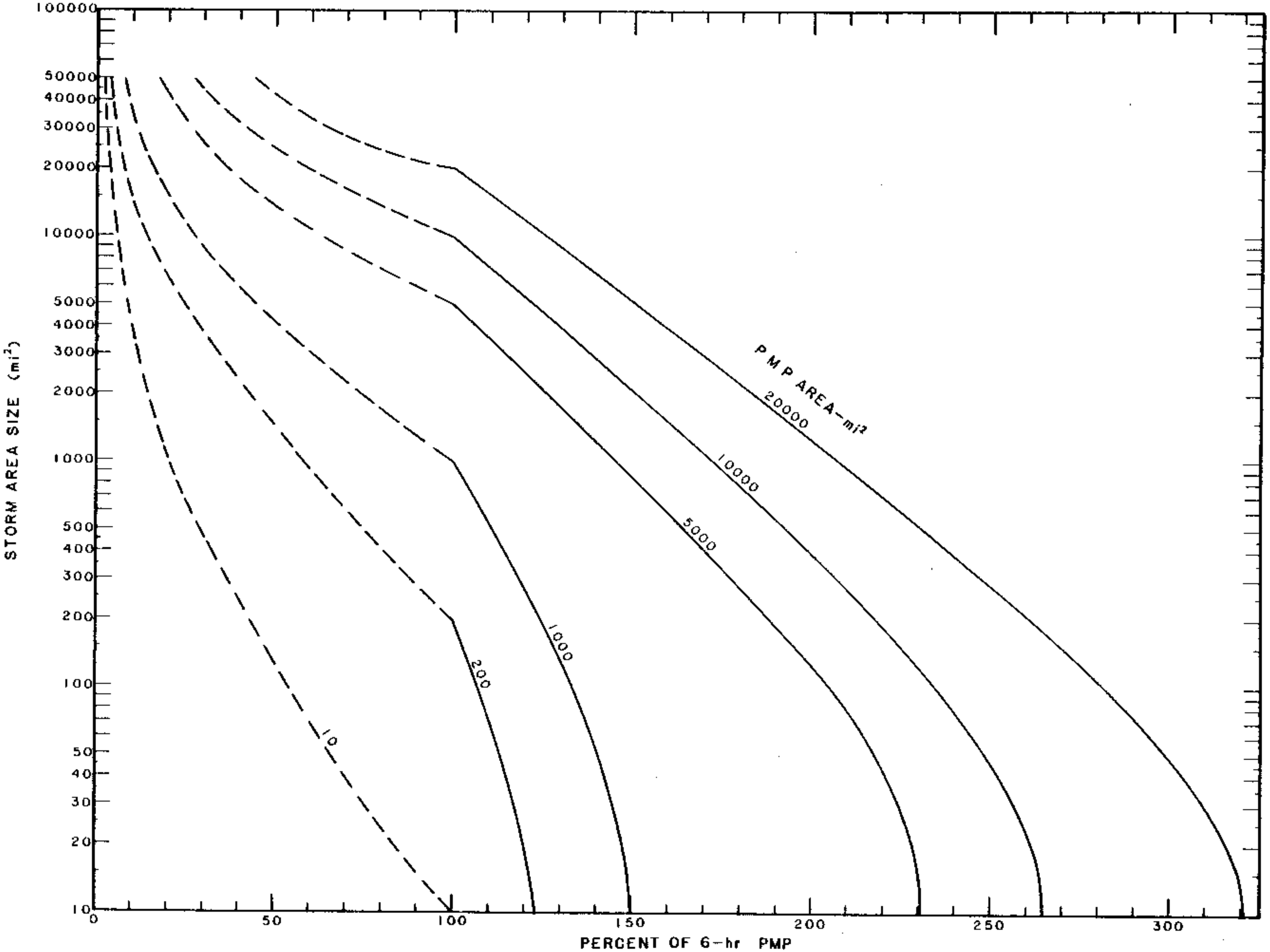

Figure 13.--6-hr within/without-storm average curves for standard area sizes.

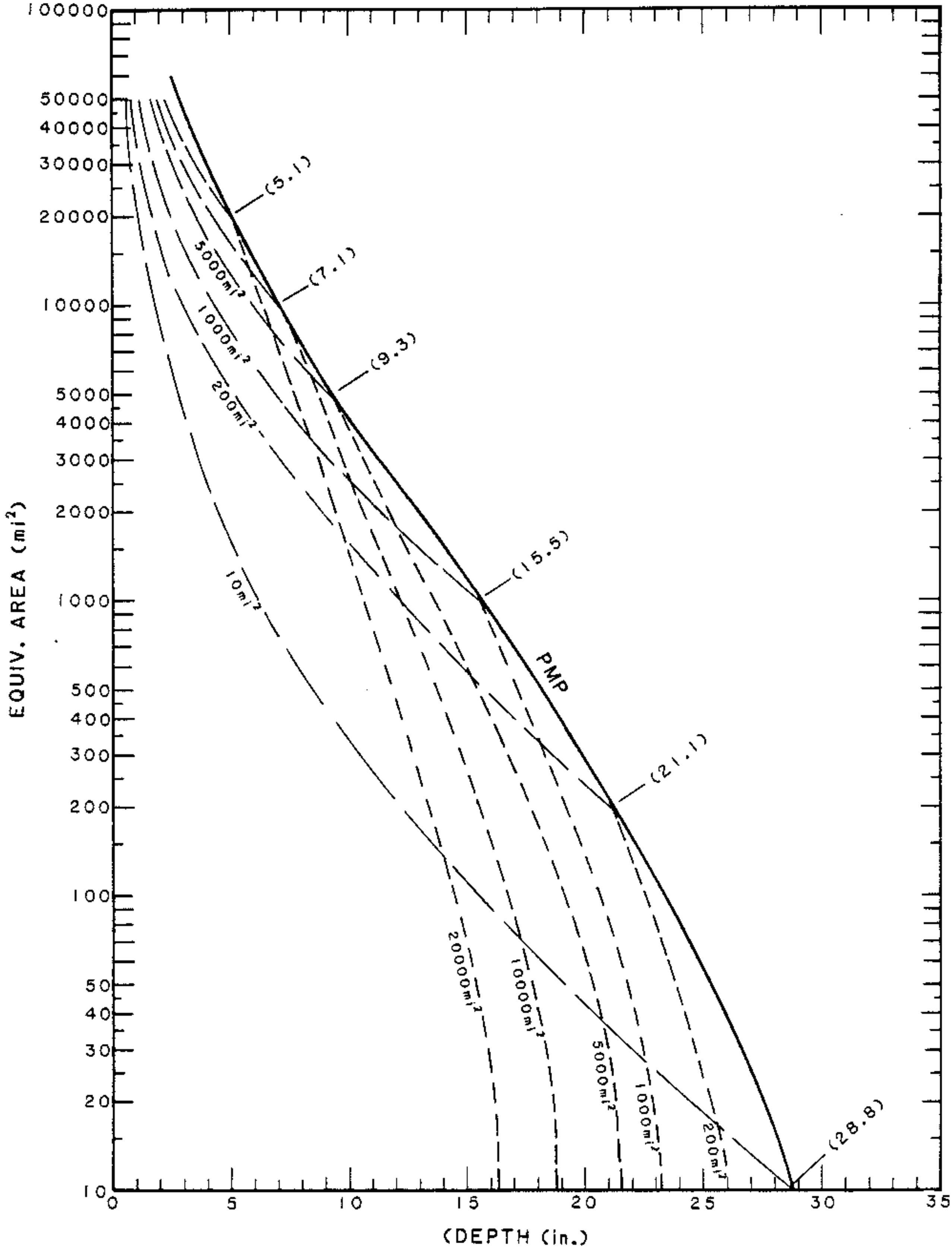

Figure 14.—Within/without-storm curves for PMP at 37°N, 89°W for standard area sizes.

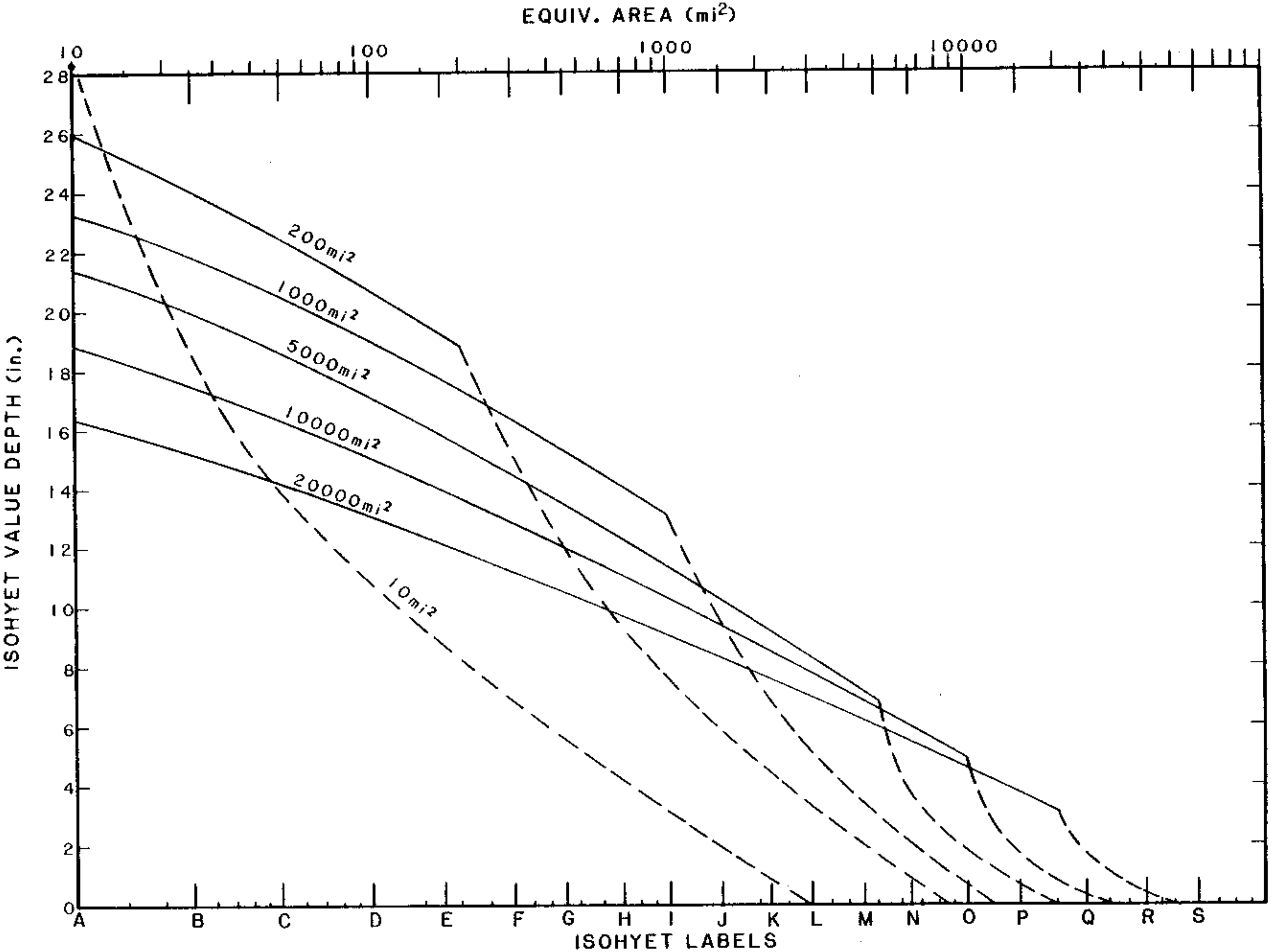

Figure 15.—Isohyetal profiles for standard area sizes at 37°N, 89°W.

determine the corresponding profiles. We applied the procedure to obtain isohyetal profiles for the standard area sizes, as shown in figure 15.

In figure 15, the solid lines represent the profile corresponding to the short-dashed curves in figure 14. A discontinuity occurs at the point of PMP, and the dashed lines are the converted long-dashed lines in figure 14 representing residual precipitation. Vertical lines labeled A,B,C,...,S are indicated to show the specific isohyets we chose for our idealized pattern in figure 5. Should supplemental isohyets be of interest, they may be interpolated from the scale of enclosed areas along the top of this figure.

To apply figure 15 for a PMP pattern of 1,000 mi^2, for example, enter the abscissa at each of the isohyets and move vertically to intersect the curve for 1,000 mi^2. Then, move horizontally to the left to read the respective value of the isohyet. Note that the I isohyet for the 1,000-mi^2 pattern from figure 15 is 13.0 in., while the 1,000-mi^2 PMP at 37°N, 89°W from figure 14 is 15.5 in. This says that to obtain an areal average of 15.5 in., the precipitation varies across the pattern from a central value of 23.3 in. to 13.0 in. at the enclosing isohyet.

5.2.2.3 Nomogram for isohyet values. The isohyet values in figure 15 were computed for PMP at 37°N, 89°W, but we see in HMR No. 51 that the magnitude of PMP varies regionally, and therefore we must have profiles to cover PMP for all locations. It was decided that the simplest way to handle this was to normalize the regional differences in PMP by converting the profiles in figure 15 to a percentage of the greatest 6-hr increment of PMP (the same as the 6-hr PMP). For example, as mentioned in section 5.2.2.2, the 1,000-mi^2 PMP is 15.5 in. The isohyet value for the C isohyet is 20.5 in. from figure 15. Dividing 20.5 by 15.5 gives roughly 132 percent. If we compute similar ratios for the C isohyet for other area sizes and PMP, then we have a set of values representing the variation of the C isohyet values with area size. Connecting these percentages with a smooth line, we obtain the curve labeled C in figure 16. The other lines in this figure represent similar connections of values for the other isohyets in our idealized pattern (solid lines for PMP and dashed lines for residual precipitation). We have in figure 16 a nomogram that provides the isohyet value as a percent of the greatest 6-hr increment of PMP for any location and area size for all the isohyets in our standard pattern (fig. 5). Some additional smoothing was necessary to obtain a consistent set of curves.

Once all the curves had been smoothed for the 1st 6-hr nomogram, a check was made using the average storm area size PMP depth from HMR No. 51 equated to the average PMP depth spatially distributed over the PMP portion of the storm pattern for a similar storm area size. The check was made by assuming drainages to have perfect 2.5 to 1 elliptical shapes for each of the standard area sizes. By taking the 6-hr PMP for a particular location, we read off percentage values for each of the isohyets, say for the 1,000-mi^2 area pattern (isohyets A to I), and used our computational procedure (see discussion for figure 43) to compute the precipitation volume. Dividing the volume by the area gave an average depth which should agree with that from HMR No. 51, for that location. This was done for each area size. If our results disagreed with those from HMR No. 51, we applied a percentage adjustment, comparable to the disagreement, to the points in figure 16, as a correction. The final nomogram was checked at a number of regional locations to verify that all variations from average PMP in HMR No. 51 were less than 2%.

In figure 16, the cusps represent the discontinuity points in figure 15, and although there is a question whether first-order discontinuities occur in an actual precipitation pattern, and while actual discontinuities in rainfall patterns may not exist in the regions of moderate or heavy rainfall, these are regions where the gradients of rainfall change rapidly. Our capability to represent such changes are limited and we have chosen to show them as a cusp. The discontinuities in figure 16 indicate that the gradient of the respective isohyet value variation with area size changes at that point.

To use the nomogram in figure 16 for distributing the 1,000-mi^2 PMP, one enters the figure at 1,000 mi^2 on the ordinate and reads from right to left at the points of intersection with the respective curves. That is, values of approximately 149, 140, 131,..., 82 percent are obtained for isohyets A, B, C,...,I contained within the 1,000-mi^2 ellipse, and 60, 44, 32, 21, 12, and 5 percent are obtained for the isohyets of residual precipitation (J to O) outside the 1,000-mi^2 ellipse.

5.2.3 Isohyet values for the second greatest 6-hr PMP increment

Section 5.2.2 describes the development of the procedure to obtain isohyet values for the greatest 6-hr PMP increment. We wish to follow a similar procedure to obtain isohyet values for the second greatest 6-hr PMP increment. To do this, however, we need to return to our data base of storms in table 1 and find the set of storms whose 12-hr moisture maximized and transposed rainfall came within 10 percent of the 12-hr PMP. The 12-hr depth-area data for these storms were used to compute ratios at all the available area sizes. Again, the ratios were averaged and these average ratios plotted against area size to get the 12-hr within/without-storm curves shown in figure 17. Then we converted the curves in figure 17 to depths relative to the 12-hr PMP at 37°N, 89°W (not shown). The computational procedure (World Meteorological Organization 1973) was used again to obtain 12-hr isohyetal profile curves (not shown). At this point, we subtracted the 6-hr isohyetal profile data from the 12-hr profile data to get profiles for the 2nd 6-hr increment (not shown). Then, reading depths for the standard isohyets chosen in figure 5 and converting these into a percentage of the 2nd 6-hr increment of PMP, we developed the 2nd 6-hr nomogram shown in figure 18.

Once again, a check was made for accuracy as represented by the average PMP data from HMR No. 51, and appropriate adjustments and smoothing made where needed. The set of solid curves in figure 18, representing isohyets within the PMP area, tends to have shifted closer to the 100 percent value. This is expected, because as we mentioned earlier, by the fourth increment little to no areal distribution was evident in our study computations; i.e., a value of 100 percent of the incremental PMP applies throughout the PMP portion of the pattern storm (this does not include residual precipitation).

5.2.4 Isohyet values for the third greatest 6-hr PMP increment

We used the observation of converging values discussed in section 5.2.3 to obtain isohyet values for the third greatest 6-hr PMP increment, rather than repeat the complex procedure followed for the greatest and second greatest

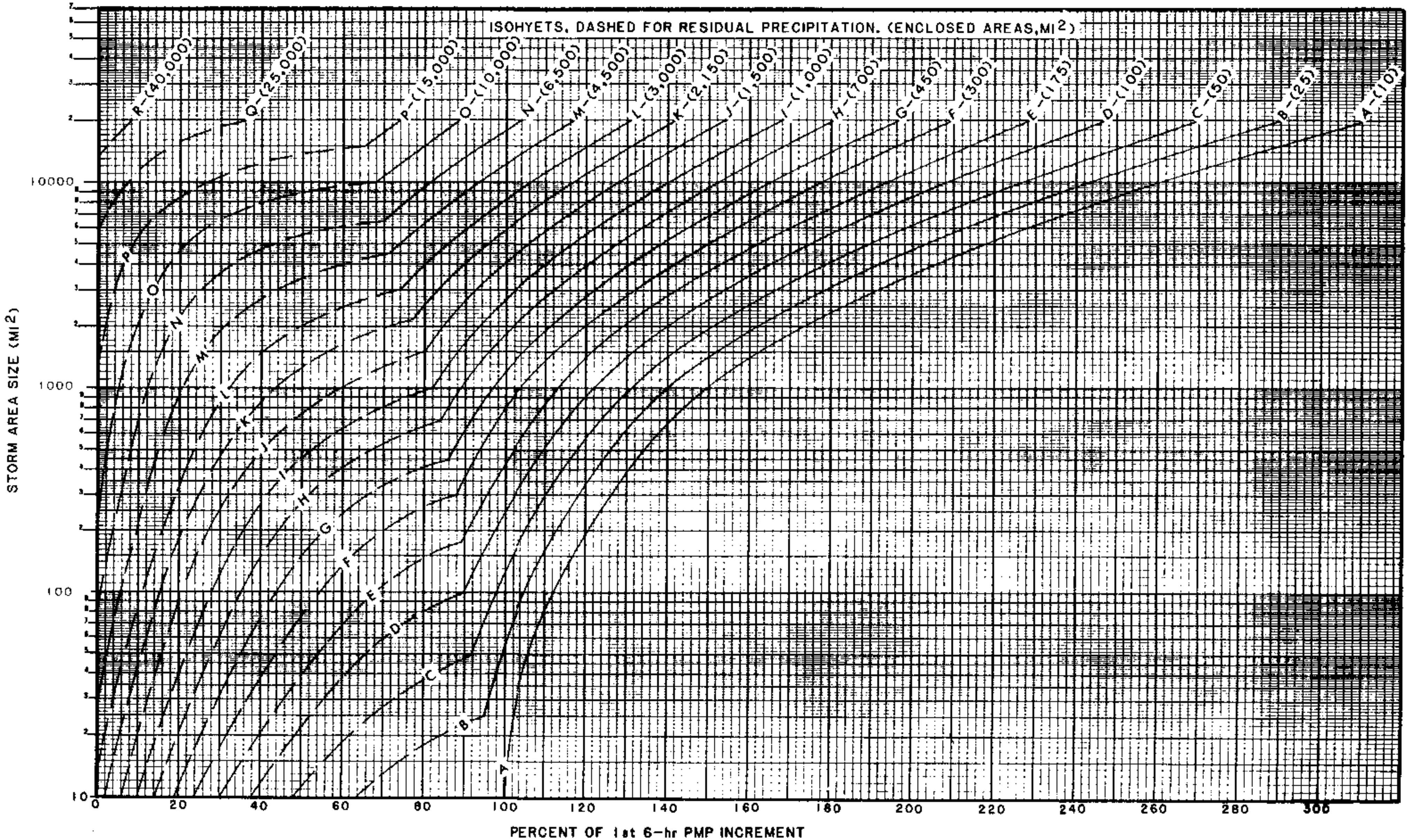

Figure 16.--Nomogram for the 1st 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi².

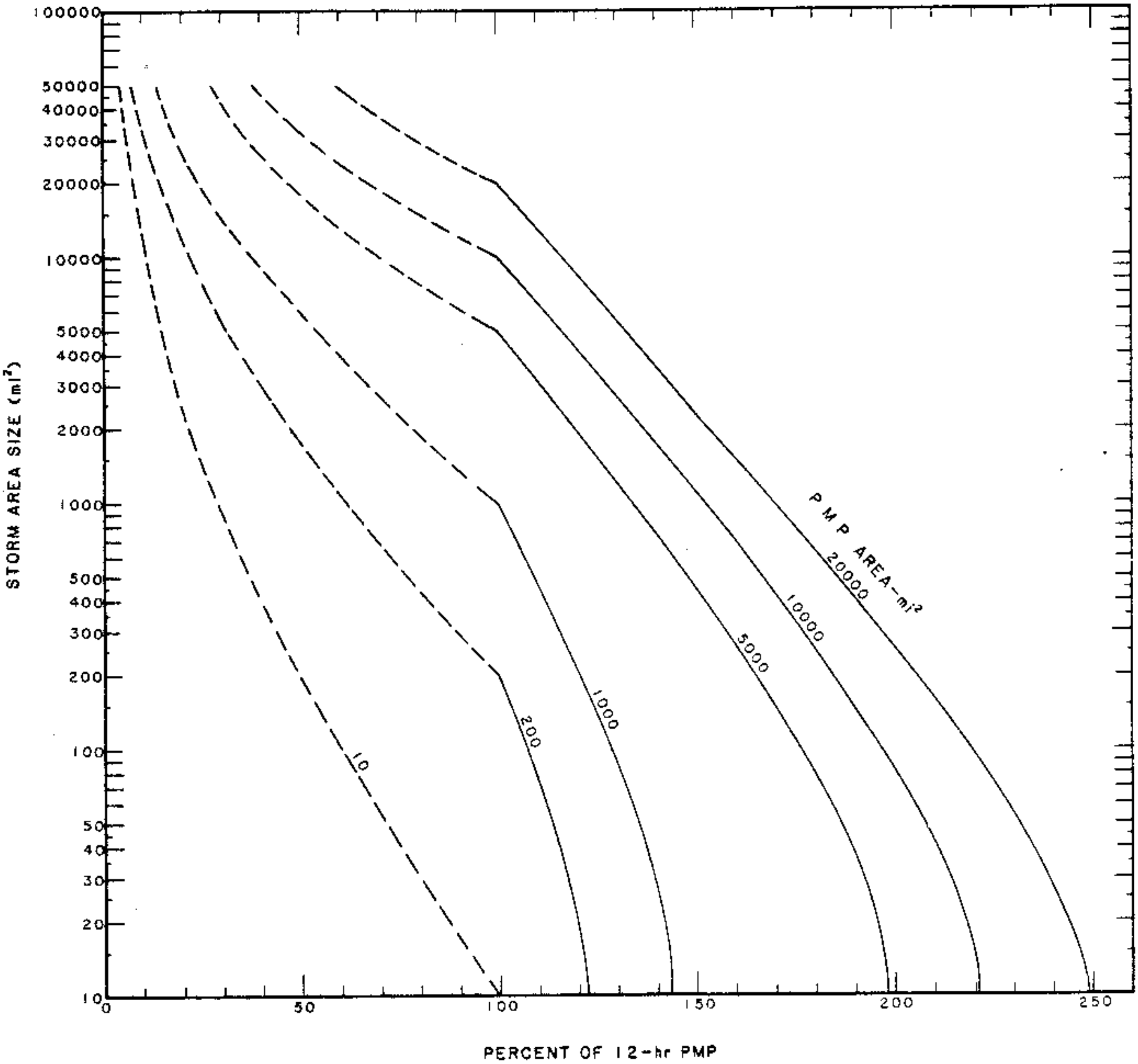

Figure 17.—12-hr within/without-storm curves for standard area sizes.

increments. Therefore, we plotted the values of the first and second greatest 6-hr PMP increments for each isohyet from the respective nomograms (figs. 16 and 18) and connected them with a smooth curve to a value of 100 percent used to represent the fourth increment. From these simple curves, we then interpolated the percents for the third 6-hr PMP increment. One advantage of this procedure was that it guaranteed consistency between results.

The results of this interpolative scheme are shown in figure 19 in percent of the third greatest 6-hr PMP increment. In this figure, we see that the respective curves for PMP (solid lines) are very near to 100 percent. Note the difference in scale of the abscissa between PMP curves and residual precipitation curves, made to facilitate their use. These curves were also checked for

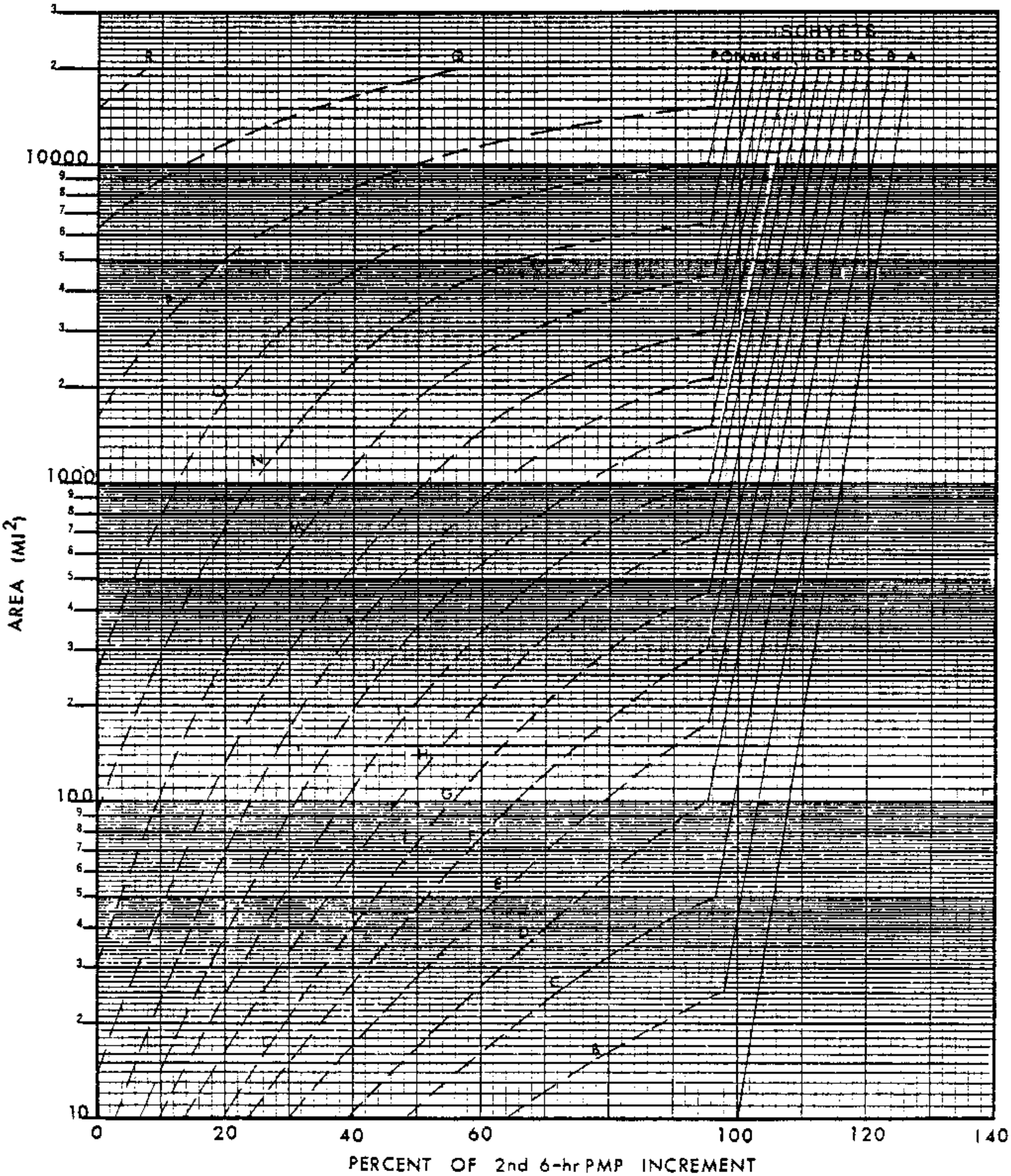

Figure 18.--Nomogram for the 2nd 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi^2.

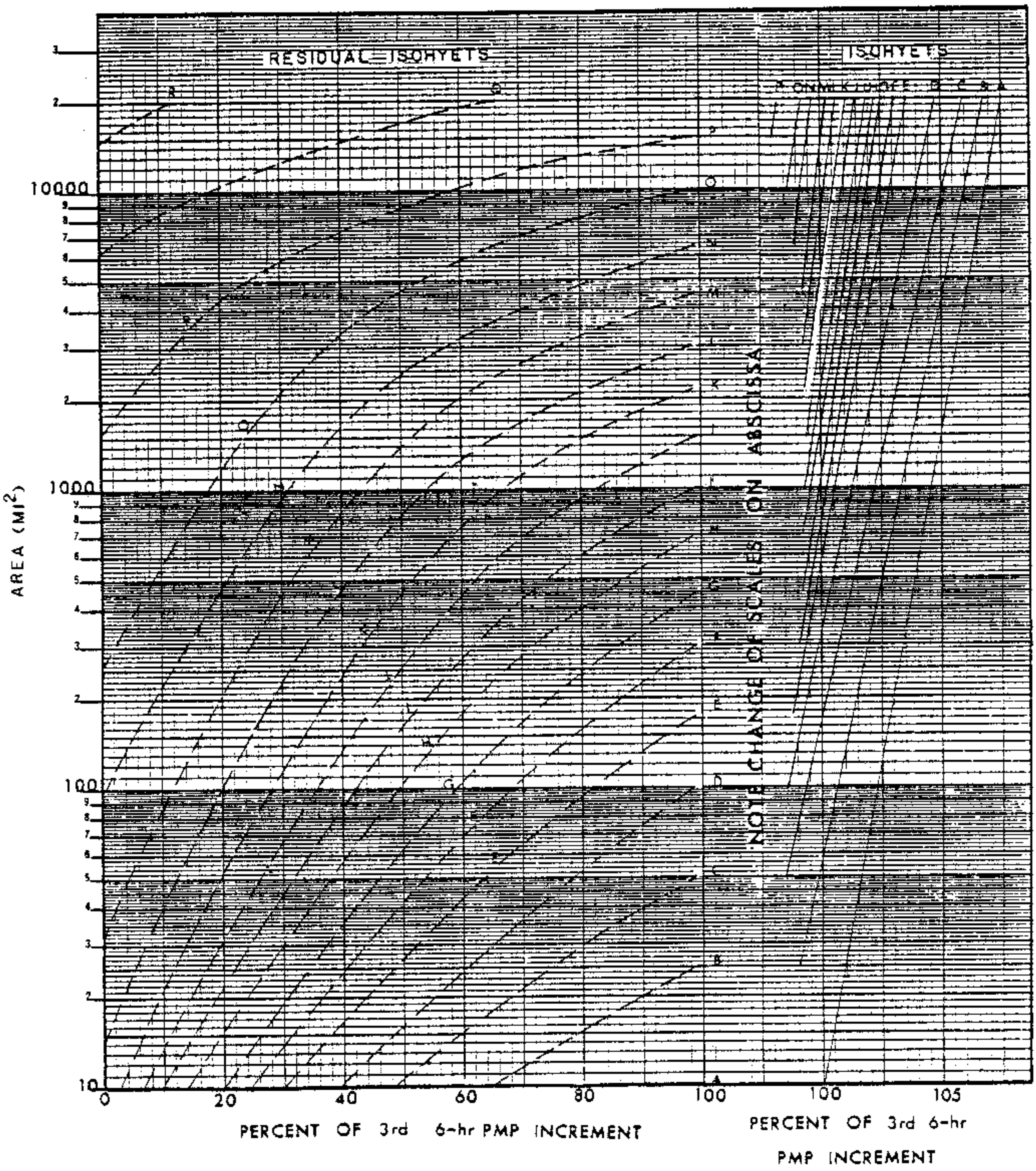

Figure 19.—Nomogram for the 3rd 6-hr PMP increment and for standard isohyet area sizes between 10 and 40,000 mi^2.

agreement with HMR No. 51 as described for the previous two 6-hr increment nomograms.

5.2.5 Residual-area precipitation

The nomograms in figures 16, 18 and 19 were believed sufficient to provide areal distribution of PMP within any pattern area and location. It was mentioned in section 3.5.3, that it was necessary to introduce the concept of residual precipitation, i.e., that which fell outside the area for which PMP was being distributed. Residual precipitation is needed to cover the remainder of the drainage not covered by the elliptical pattern for the area of the PMP. In each of the nomograms the dashed curves give isohyet values for application to the uncovered drainage. For the fourth through 12th increments, we have said that a constant value applies to the area of PMP being considered.

Outside this area, there would be a decrease in the precipitation from that of the PMP pattern. The distribution of this residual precipitation for the fourth to 12th increments was determined from the tendencies shown for the residual precipitation isohyet values in figures 16, 18 and 19. The results of extrapolation from these relations are presented as a nomogram for the fourth through 12th 6-hr increments, in figure 20. Note these curves all start from 100%, as compared to the residual precipitation curves in figure 19.

To emphasize the difference between precipitation patterns for the 1st three nomograms and that for figure 20, we show two schematic diagrams in figure 21 for a PMP pattern of 1,000 mi^2, as an example. The figure at the top represents a pattern of isohyets for which values are obtained for the three greatest 6-hr PMP increments. The figure at the bottom shows the pattern of isohyets for which values are obtained for the fourth through 12th 6-hr PMP increments of 1,000-mi^2 PMP pattern. Residual precipitation in both diagrams is indicated by the dashed lines. We have added an irregularly shaped drainage to the patterns in figure 21 to clarify the point that there will be a reduction in the volume of precipitation that occurs even for the fourth through 12th 6-hr periods. That is, even though a constant value applies across the drainage as shown by the I isohyet, only a portion of the area enclosed by this isohyet lies within the drainage.

5.2.6 Tables of nomogram values

We have found that different users read slightly different values from the set of nomogram figures provided in this study. To minimize such differences and since the reading of values from these figures is a recurrent process in the application procedure outlined in chapter 7, it was decided that values read from the nomograms would be provided in tabular form. Reference to the tables when making the computations in chapter 7 will assure all users have the same values. Tables 15 to 18 provide nomogram values for each of the standard isohyet area sizes and for an intermediate area size between each of the standard isohyet area sizes.

Note that, although these tables are useful for all computations, it may still be necessary to refer to the nomograms on occasion. One such ocassion would be when one wishes to distribute PMP over an area size other than one of the

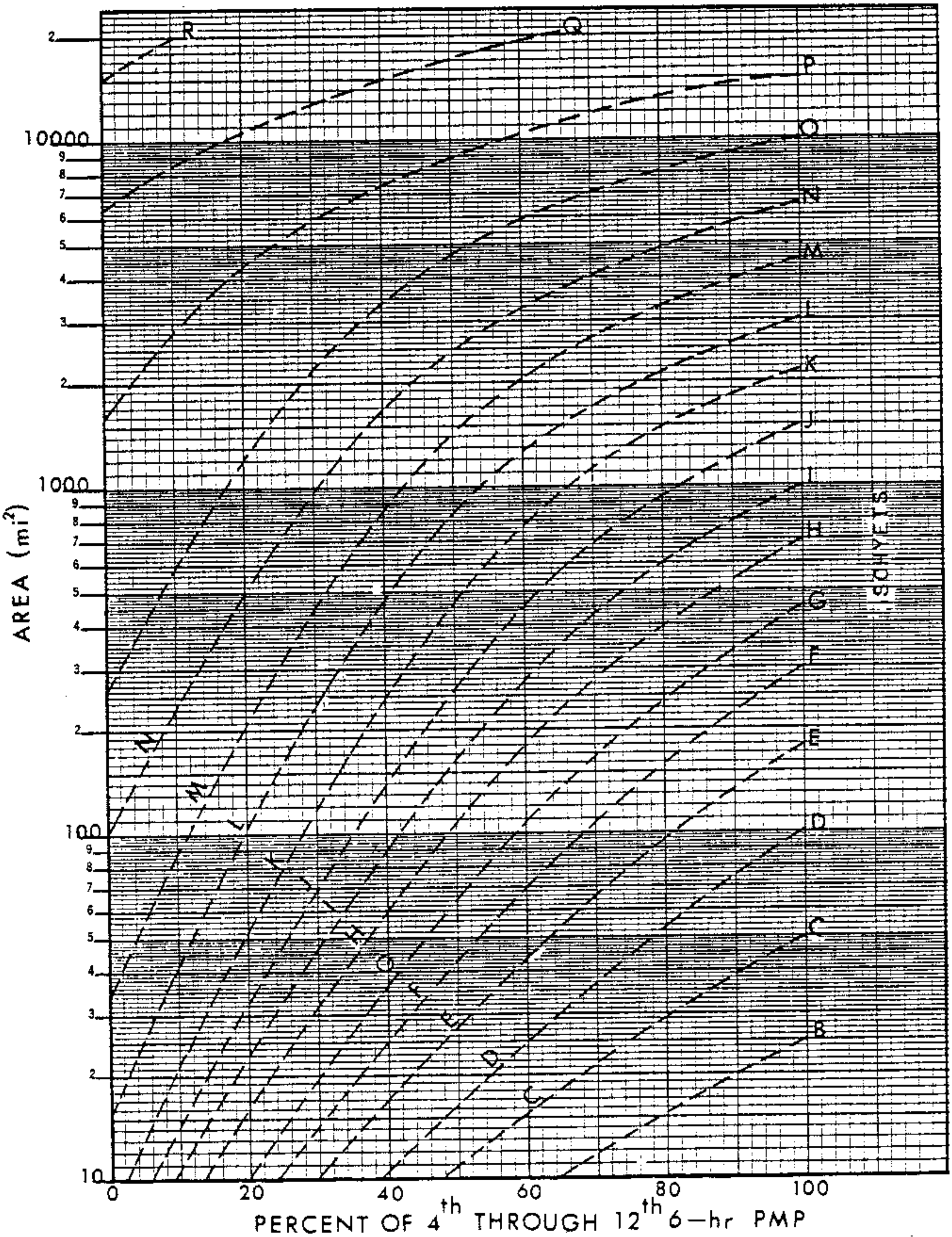

Figure 20.--Nomograms for the 4th through 12th 6-hr PMP increments and for standard isohyet area sizes between 10 and 40,000 mi^2.

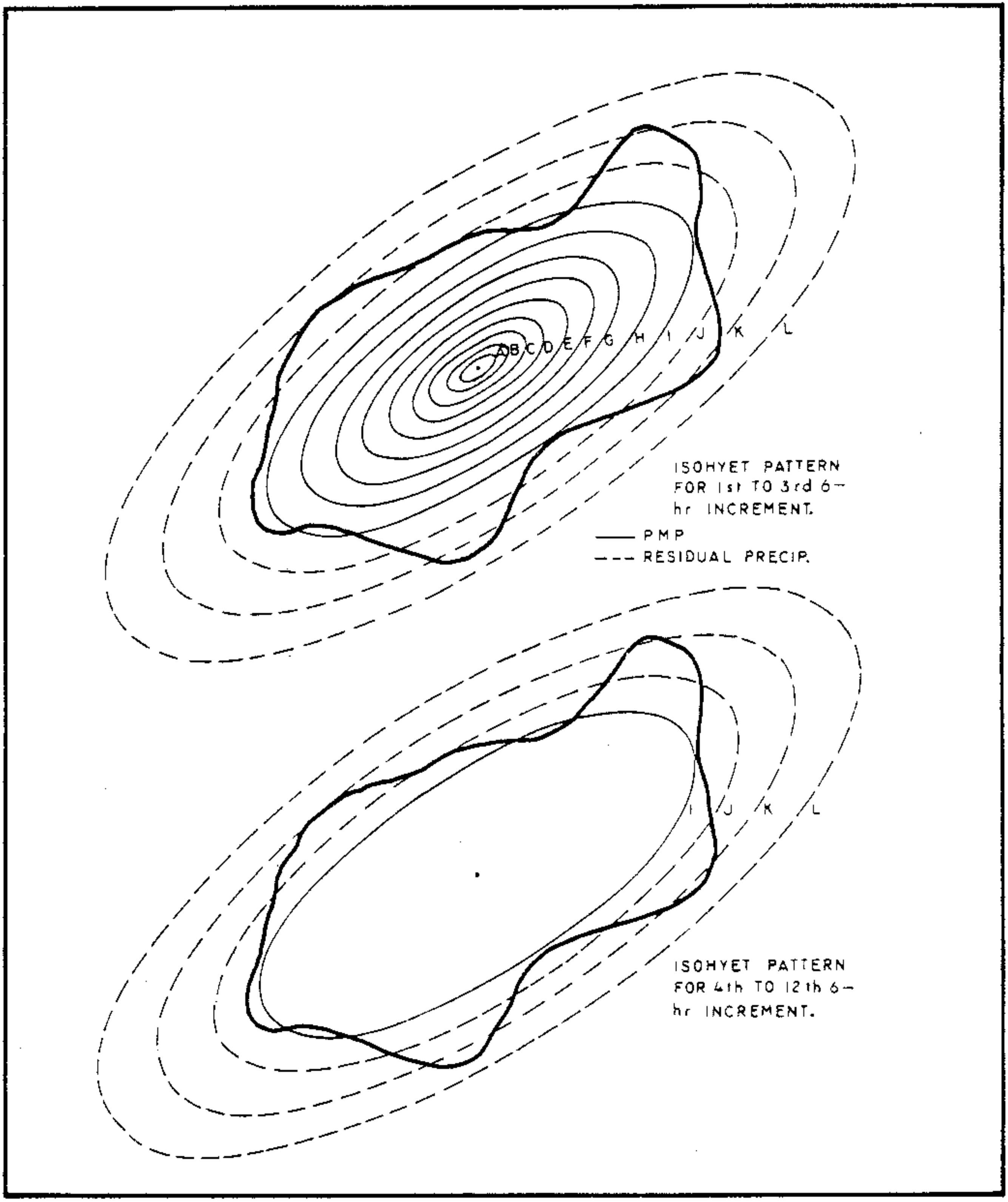

Figure 21.—Schematic showing difference in isohyetal patterns for 3 greatest 6-hr PMP increments and that for 4th through 12th 6-hr increments for a 1,000-mi^2 storm.

Table 15.—1st 6-hr nomogram values at selected area sizes

	Storm Area (mi^2) size											
Isohyet	10	17	25	35	50	75	100	140	175	220	300	360
A	100*	101	102	104	106	109	112	116	119	122	126	129
B	64	78	95*	97	99	102	105	108	111	114	118	121
C	48	58	67	77	92*	95	98	101	103	106	110	113
D	38	46	52	59	66	77	90*	93	96	99	103	105
E	30	37	43	48	54	62	68	78	89*	92	96	98
F	24	30	34	39	44	50	55	61	66	73	88*	90
G	19	24	28	32	35	40	44	49	53	58	65	73
H	14	19	22	25	28	32	35	39	42	46	51	56
I	10	14	17	19	22	26	28	32	34	37	42	45
J	6	9	12	14	16	19	21	24	26	28	32	35
K	2	5	7	9	11	14	16	18	20	22	25	27
L	0	1	3	5	7	9	11	13	15	17	19	21
M		0	0	1	3	5	6	8	9	10	12	13
N				0	0	0	1	2	3	4	6	7
O							0	0	0	0	1	2
P											0	0

*Indicates cusp.

Table 15.--1st 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size											
	450	560	700	850	1000	1200	1500	1800	2150	2600	3000	3800
A	132	136	140	145	149	155	162	169	176	184	191	203
B	124	128	132	136	140	145	152	158	165	172	179	189
C	116	120	124	128	131	136	142	147	154	160	166	176
D	108	111	115	119	122	126	132	137	142	148	154	163
E	101	104	107	110	113	116	122	126	131	137	142	150
F	93	95	98	101	104	107	112	117	122	127	132	140
G	86*	89	92	94	97	100	105	108	113	118	122	130
H	63	72	84*	87	89	92	96	99	103	108	112	119
I	50	56	63	72	82*	85	88	91	95	99	102	108
J	38	43	48	54	60	68	80*	83	86	89	92	98
K	30	33	36	40	44	49	56	64	77*	80	83	89
L	23	25	27	30	32	35	41	46	52	62	74*	79
M	15	16	18	19	21	23	26	29	33	38	44	56
N	8	9	10	11	12	14	16	18	20	22	25	31
O	3	3	4	4	5	6	7	8	9	11	13	15
P	0	0	0	0	0	0	0	1	2	3	4	6
Q								0	0	0	0	0

*Indicates cusp

Table 15.--1st 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size								
	4500	5500	6500	8000	10000	12000	15000	18000	20000
A	212	223	233	247	262	274	290	304	312
B	198	209	218	230	243	255	271	283	291
C	184	194	203	214	227	238	253	264	271
D	170	180	187	198	209	219	232	242	248
E	157	166	174	183	194	203	214	224	229
F	146	153	160	169	178	186	196	205	210
G	135	142	148	157	166	174	183	192	197
H	124	131	137	144	152	159	168	176	181
I	113	119	125	132	140	147	156	164	168
J	103	108	113	120	128	135	143	150	154
K	93	98	103	110	117	123	131	138	142
L	83	88	93	99	107	113	120	127	131
M	71*	76	81	87	93	99	106	113	117
N	37	48	70*	75	82	87	94	101	104
O	19	23	29	40	68*	73	80	86	89
P	8	10	13	18	26	38	65*	71	74
Q	0	0	1	3	7	11	18	28	36
R			0	0	0	0	2	6	8
S							0	0	0

*Indicates cusp

Table 16.--2nd 6-hr nomogram values at selected area sizes

	Storm area (mi^2) size											
Isohyet	10	17	25	35	50	75	100	140	175	220	300	360
A	100*	102	103	104	105.5	107	108	109	110	110.5	111.5	112
B	64	81.5	98*	99	100.5	102	103	104	105	106	107	108
C	48	61	72	82	96.5*	98	99	100.5	101.5	102.5	103.5	104
D	39	50	59	66.5	76	86	95*	96.5	97.5	98.5	100	101
E	30	40	48	54.5	62.5	72	79	88	95*	96	97.5	98.5
F	24	32	39	44.5	51	59.5	65	73	79	85	95*	96
G	20	27	32.5	37.5	43.5	50	55	62	66.5	72	80	85
H	14	20.5	26	30.5	36	42	47	52.5	56.5	61	67.5	72
I	10	15.5	20	24	29	34.5	38.5	43.5	47	51	57	61
J	7	12	15.5	19	23	27.5	31	35	38.5	42	47	50
K	3	7	10.5	13.5	17	21	24	27.5	30	33	37.5	40.5
L	0	1.5	5	7.5	11	14.5	17	20.5	23	26	30	33
M		0	0	1	4	7	9	12	14.5	17	20.5	23
N				0	0	0	1	3.5	5	7.5	10	12
O							0	0	0	0	1	3
P											0	0

*Indicates cusp

Table 16.--2nd 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size										
	450	560	700	850	1000	1200	1500	1800	2150	2600	3000	380
A	113	114	114.5	115	116	116.5	117	118	118.5	119	119.5	120.5
B	109	109.5	110	111	112	112.5	113	114	114.5	115.5	116	117
C	105	106	107	107.5	108.5	109	110	110.5	111	112	112.5	113.5
D	102	102.5	104	104.5	105	106	107	108	108.5	109.5	110	111
E	99.5	100.5	101	102	103	104	105	105.5	106.5	107	108	109
F	97	98	99	100	101	102	103	104	104.5	105.5	106	107
G	95*	96	97	98	99	99.5	100.5	101.5	102	103	104	105
H	77.5	85	95*	96	97	97.5	99	99.5	100	101	102	103
I	66	71.5	78	85	95*	96	97	98	99	99.5	100.5	101.5
J	54.5	60	65.5	71	76	82.5	95.5*	96	97	98	99	100
K	44.5	49	54	58.5	63	68	75.5	83	96*	96.5	97	98
L	36.5	40	44	48	51	55	60.5	66	73	83	96*	97
M	25.5	28.5	32	35	38	41	45	49.5	54	60.5	67	81
N	14	17	19.5	22	24	27	31	34	37.5	41.5	45	52.5
O	4.5	6.5	9	11	12.5	14.5	17	19.5	22	25.5	28.5	34
P	0	0	0	0	0	0	0	1.5	4	7	9	13.5
O								0	0	0	0	0

*Indicates cusp

Table 16.--2nd 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size 4500	5500	6500	8000	10000	12000	15000	18000	20000
A	121	122	122	123	124	124.5	125	126	126
B	117	118	119	120	120.5	121	122	122.5	123
C	114	115	115.5	116.5	117	118	119	119.5	120
D	112	112.5	113	114	115	116	117	118	118
E	109.5	110.5	111	112	113	114	115	116	116
F	108	108.5	109	110	111	112	113	113.5	114
G	105.5	106.5	107	108	109	110	111	112	112
H	103.5	104.5	105	106	107	108	109	110	110
I	102	103	104	104.5	105.5	106.5	107	108	108.5
J	100.5	101.5	102	103	104	105	106	106.5	107
K	99	100	100.5	101.5	102.5	103	104	105	105
L	97.5	98.5	99	100	101	102	102.5	103.5	104
M	96*	97	97.5	98.5	99	100	101	102	102
N	59	72.5	95.5*	96	97	98	99	99.5	100
O	39	46	52.5	66	95*	96	97	97.5	98
P	17	22	27.5	37	50	64	96*	96.5	97
Q	0	0	1	6	14	21	34	47	55
R		0		0	0	0	0	4.5	7
S									0

*Indicates cusp

Table 17.—3rd 6-hr nomogram values at selected area sizes

	Storm area (mi^2) size											
Isohyet	10	17	25	35	50	75	100	140	175	220	300	360
A	100*	100.6	101	101.3	101.6	102	102.3	102.6	102.8	103.1	103.4	103.6
B	65	83.5	99*	99.4	99.8	100.3	100.7	101	101.3	101.5	101.9	102.1
C	48	63	74.5	85.5	98.5*	99	99.3	99.7	100	100.3	100.7	100.9
D	39	51	60.5	69	78.5	90	98.6*	99	99.2	99.5	99.8	100.1
E	30	40	48.5	55.5	63	73.5	81.5	92	98.8*	99	99.3	99.5
F	24	33	40	46.5	53.5	61.5	68	76.5	83	89	99.0*	99.2
G	20	28	34	39.5	46	53	59	66	71	77	86	92
H	14	21	27	32.5	37.5	44	49	55	59.5	64	72	76.5
I	10	16.5	21.5	26.5	31.5	37.5	42	47.5	51	55.5	62	66
J	6.5	12.5	17	21	26	31.5	35.5	40.5	44	47.5	53	56
K	3	7.5	11.5	15	19.5	24.5	28	32.5	35	38.5	43	46
L	0	1.5	5	8.5	12	16.5	20	24	26.5	29.5	33.5	36
M		0	0	1	4	8.5	11.5	15	18	20.5	24.5	27
N				0	0	0	1	4.5	7	10	14	16
O							0	0	0	0	2	4
P											0	0

*Indicates cusp

Table 17.—3rd 6-hr nomogram values at selected area sizes - Continued

	Storm area (mi^2) size											
Isohyet	450	560	700	850	1000	1200	1500	1800	2150	2600	3000	3800
A	103.8	104	104.2	104.4	104.6	104.7	105	105.2	105.3	105.5	105.7	105.8
B	102.4	102.7	102.9	103.2	103.3	103.5	103.8	104	104.2	104.4	104.6	104.8
C	101.2	101.5	101.7	102	102.3	102.5	102.7	102.9	103.2	103.4	103.5	103.8
D	100.3	100.6	100.8	101.1	101.3	101.5	101.7	102	102	102.4	102.5	102.8
E	99.8	100	100.2	100.4	100.6	100.8	101	101.2	101.3	101.5	101.7	101.9
F	99.5	99.7	99.9	100.1	100.3	100.4	100.7	100.8	101	101.2	101.3	101.5
G	99.2*	99.4	99.6	99.7	99.9	100	100.3	100.4	100.6	100.7	100.9	101.1
H	84	91	99.2*	99.4	99.6	99.7	100	100.1	100.3	100.4	100.5	100.7
I	71	77.5	85	92	99.3*	99.5	99.7	99.8	100	100.1	100.2	100.5
J	60	64.5	70.5	76.5	82.5	89.5	99.4*	99.5	99.7	99.8	99.9	100.1
K	50	54	58.5	62.5	67	72.5	81	89	99.5*	99.5	99.6	99.8
L	39.5	43	47	50.5	54	58.5	65.5	72.5	80.5	90.5	99.3*	99.5
M	30	33	37	40	43	46.5	51.5	56.5	61	69	76	88.5
N	19	22.5	25.5	28.5	31	34	38	42	46.5	52	57	67
O	7	10	13	15.5	17.5	20.5	24	27	30.5	34	37.5	43.5
P	0	0	0	0	0	0	0	2.5	5.5	9	12	16.5
Q									0	0	0	0

*Indicates cusp

Table 17.--3rd 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size								
	4500	5500	6500	8000	10000	12000	15000	18000	20000
A	106	106.2	106.4	106.6	106.8	107	107.2	107.4	107.5
B	105	105.3	105.5	105.7	106	106.2	106.5	106.7	106.8
C	104	104.3	104.5	104.8	105	105.3	105.5	105.8	105.9
D	103.1	103.2	103.5	103.7	104	104.2	104.4	104.6	104.7
E	102.1	102.3	102.5	102.7	102.8	103	103.3	103.5	103.6
F	101.7	101.8	102	102.2	102.4	102.6	102.8	103	103
G	101.2	101.4	101.5	101.7	101.9	102.1	102.3	102.4	102.5
H	100.9	101.1	101.2	101.4	101.6	101.8	102	102.2	102.2
I	100.6	100.8	100.9	101.1	101.3	101.5	101.7	101.8	101.9
J	100.2	100.4	100.5	100.7	100.9	101	101.2	101.3	101.4
K	99.9	100	100.2	100.3	100.5	100.7	100.8	101	101.1
L	99.6	99.7	99.8	100	100.2	100.3	100.5	100.6	100.7
M	99.3*	99.4	99.5	99.6	99.8	99.9	100.1	100.2	100.2
N	76	88	98.9*	99	99.2	99.3	99.5	99.6	99.7
O	49	57	65	79	98.7*	98.8	99	99.1	99.2
P	21	27.5	34.5	44.5	59	71.5	98*	98.7	98.2
Q	0	0	1	8	18	27.5	42	54.5	66
R			0	0	0	0	1	7.5	12
S							0	0	0

*Indicates cusp

Table 18.--4th to 12th 6-hr nomogram values at selected area sizes

Isohyet	Storm area (mi^2) size											
	10	17	25	35	50	75	100	140	175	220	300	360
A	100											
B	65	83.5	100									
C	48	62.5	74.5	86	100							
D	39	50.5	60.5	68.5	78.5	89.5	100					
E	30	40	48.5	55	63	73	81.5	91	100			
F	24	33	40	46	53.5	61.5	68	76.5	83	89	100	
G	20	27.5	34	39	46	53	59	65.5	71	77	86	91.5
H	14	21	27	31.5	37.5	44	49	55	58.5	64	72	77
I	10	16	21.5	26	31.5	37	42	47.5	51	55	62	65.5
J	6.5	12	17	21	26	31	35.5	40	44	47	53	55.5
K	3	7.5	11.5	15	19.5	24	28	32	35	38.5	43	46
L	0	0.5	5	8.5	12	16	20	23.5	26.5	29	33.5	36
M		0	0	0.5	4	8.5	11.5	15	18	20.5	24.5	27
N				0	0	0	1	4	7	9.5	14	16
O							0	0	0	0	2	4
P											0	0

Table 18.—4th to 12th- 6-hr nomogram values at selected area sizes - Continued

Isohyet	Storm area (mi^2) size											
	450	560	700	850	1000	1200	1500	1800	2150	2600	3000	3800
A												
B												
C												
D												
E												
F												
G	100											
H	84	91	100									
I	71	77.5	85	92	100							
J	60	64.5	70.5	77	82.5	89.5	100					
K	50	53.5	58.5	62	67	72	81	89	100			
L	39.5	43	47	50.5	54	58.5	65.5	72.5	80.5	90	100	
M	30	33	37	40	43	46.5	51.5	56	61	69	76	88.5
N	19	22	25.5	28	31	33.5	38	41.5	46.5	51.5	57	67
O	7	9.5	13	15	17.5	20	24	26.5	30.5	33.5	37.5	43.5
P	0	0	0	0	0	0	0	2.5	5.5	9	12	17
Q							0	0	0	0	0	

Table 18.--4th to 12th 6-hr-nomogram values at selected area sizes - Continued

	Storm area (mi^2) size								
Isohyet	4500	5500	6500	8000	10000	12000	15000	18000	20000
A									
B									
C									
D									
E									
F									
G									
H									
I									
J									
K									
L									
M	100								
N	76	88	100						
O	49	56.5	65	79	100				
P	21	27	34.5	44	59	71	100		
Q	0	0	1	8	18	27	42	54	66
R			0	0	0	0	1	7	12
S							0	0	0

standard isohyet area sizes, for which it is then necessary to construct supplemental isohyet(s). This construction is discussed in chapter 7.

5.3 Area of Pattern Applied to Drainage

Up to this point in our discussion we have not indicated specifically how we select the area size of the PMP to distribute across a particular drainage. In previous PMP studies, we have assumed that the maximum peak discharge and the maximum volume of precipitation in the drainage were represented by a basin-centered pattern for PMP equivalent to the area of the drainage. This assumption was necessary because we do not have sufficient information to determine what the hydrologically most critical condition is for peak discharge. Obviously, as precipitation patterns are moved to centering positions closer to the drainage outlet, greater peaks may occur but volume probably will be reduced.

In the present study, we have chosen to base our selection of PMP pattern on maximizing the volume of precipitation within the drainage. This eliminates the assumption used in other Hydrometeorological Reports that PMP be based on an area equal to the drainage area. Maximum volume is a function of pattern centering, of basin irregularity of shape, and of the area size of PMP distributed over the drainage. Of these, we have control over the pattern centering when we recommend that all patterns be centered to place as many complete isohyets within the drainage as possible. The irregularity of the drainage is fixed, and we are left with the area of the PMP pattern as a variable. However, the process of maximizing volume for various area sizes results in a procedure involving a series of trials.

To obtain the area that maximizes precipitation within the drainage, we propose that the user start by selecting an area size in the vicinity of that for the drainage. It is convenient to choose areas that match those for the isohyets in our idealized pattern (700, 1,500, 6,500 mi^2, etc.). Compute the volume of precipitation for each of the 3 greatest 6-hr increments of PMP at the area size chosen and obtain the total volume. Then, choose additional areas on either side of the initial choice, and evaluate the volume corresponding to each of these. By this trial process, and by plotting the results as area size (selected) vs. volume (computed), we can approximate the area size at which the volume reaches a maximum. (This may require drawing supplemental isohyets.)

This procedure will be better demonstrated by the examples presented in chapter 7. It will be found that, as experience is gained in the application of patterns to variously shaped drainages, one can do a better job at the initial selection of area sizes.

5.4 Multiple Rainfall Centers

In general, we recommend a single-centered isohyetal pattern for distributing PMP. From major storms of record we note that as the size of the rainfall pattern increases, the number of rainfall centers increases. This observation has led to the following considerations.

5.4.1 Development of a multicentered isohyetal pattern

A consideration when discussing the numbers of centers in an isohyetal pattern is how the end product (the flood peak) varies with the number of rainfall

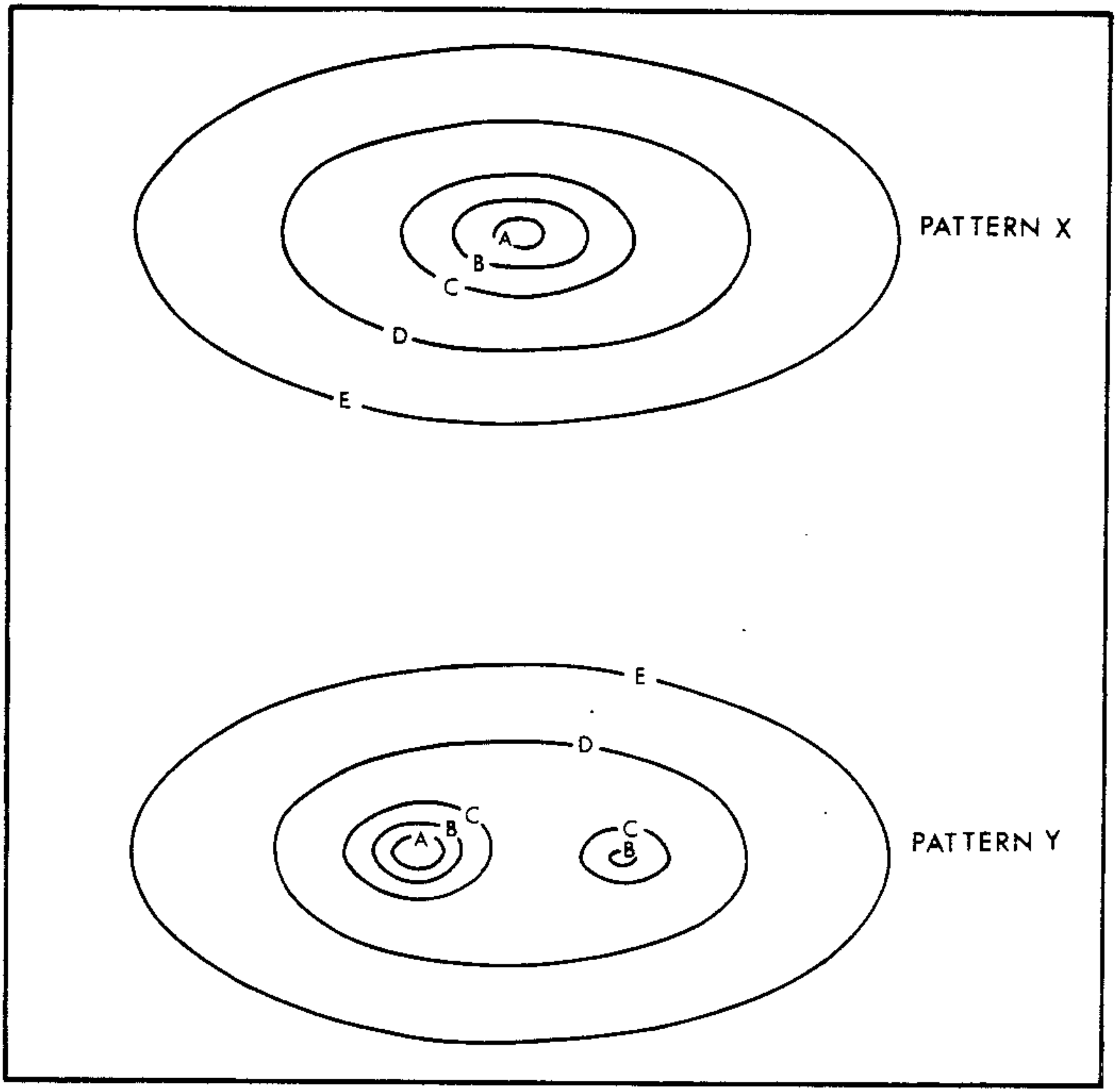

Figure 22.—Schematic showing an example of multiple centered isohyetal pattern (PMP portion only).

centers. In general, all else being equal, the more centers used, the lower the peak discharge. If multiple centers are to be considered, we therefore recommend a limit of two.

The process for deriving these centers within an elliptical pattern is based on the standard isohyets and their values for a single-centered pattern as